SNAP Engineering Overview

David Pankow

Space Sciences Laboratory,

also campus M. E. Department

University of California Berkeley

SNAP Engineering Overview

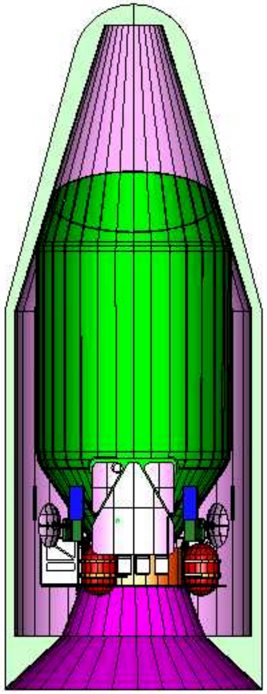
- Mission Profile
- Spacecraft and Subsystems
- Optical Telescope
    - Telescope Packaging (TMA-63)
    - Telescope Thermal
    - Camera (passive) Thermal
- Status
- R & D Manpower and Schedule
- Summary

SNAP Mission Profile

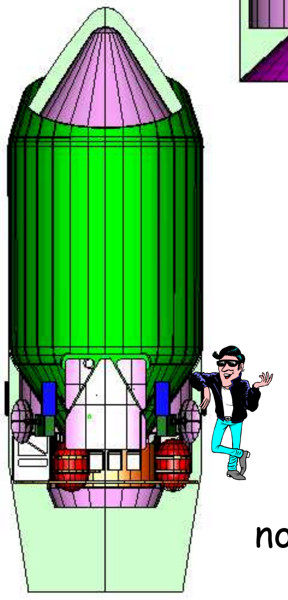
- Delta 3/4 Two Stage Launch from KSC
  - 200km x 25 Re Injection Orbit at 28°

- Hydrazine Boost to 3 day - 2.6 x 25 Re
  - Phased for near Ecliptic Plane Orbit
  - Our plus: *The perigee is Stable Over Berkeley !*

- Commissioning Phase - several overlapping weeks
  - Spacecraft Turn On Activities
  - Structured Cool Down of the Telescope
    - slow roll or auxiliary rear array
  - Degassing & Dry Out Period
  - Optics Turn On – Open Cover, Focus, etc.



Delta III



not Delta II

SNAP Mission Profile

- Mission / Science Operations
  - Alternate N/S Ecliptic Pole Observing Plan
  - Observing is suspended below 9 Re (radiation issues)
    - High Speed Data Down-Link & Onboard maintenance

- Ops Plan is Intended to be PRIMARILY a Routine Survey Mode

- and more comments…

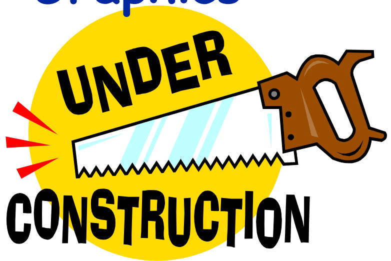
SNAP BUS PHILOSOPHY

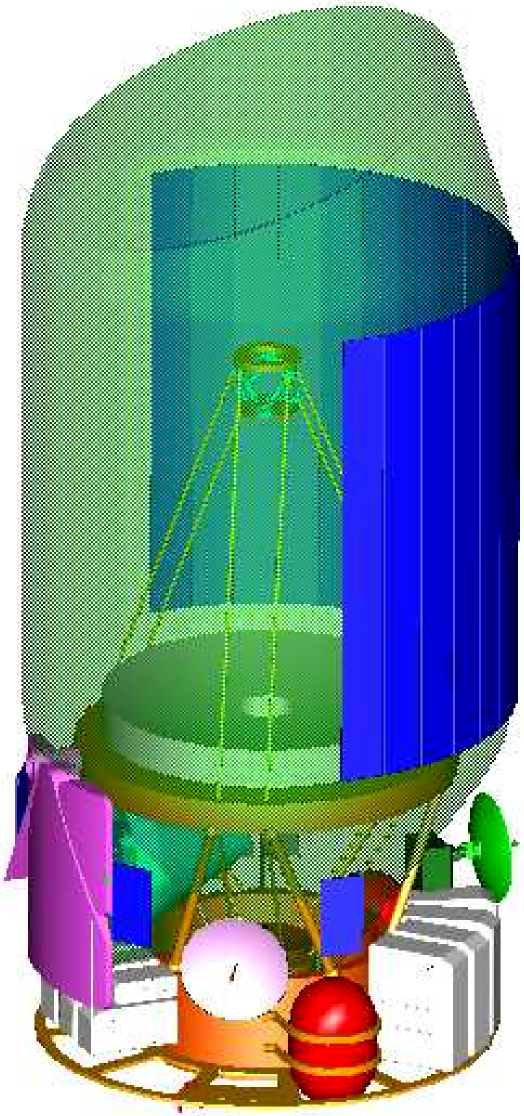
- Passive Cold Biased Bus & Baffle / Warm Optics
  - Active Coolers are not Mature, Cryogen's are Short Lived
  - High Earth Orbit allows Passive Cooling
  - Build, Test, and Fly Warm Optics (like HST)
  - Compact Telescope with the Longest Light Baffle that fits !

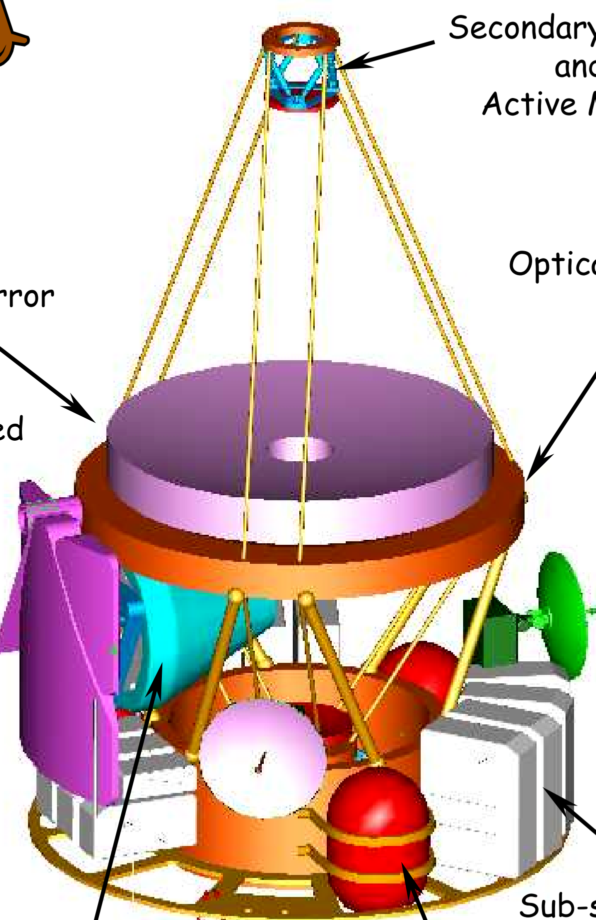
- Generic *and* Rigid Spacecraft
  - One Mission Thermal Attitude ...near Sun Line Normal Viewing
  - No Appendages and minimal mechanisms
  - On Board Angular Momentum Compensation
  - Noise Isolation at the Sources
  - Generic RSDO spacecraft - no R&D needed

Generic Spacecraft Packaging

Graphics







from GSFC - IMDC study

Needs Tertiary View...

RSDO Bus Options
(Rapid Spacecraft Development Office at GSFC)

- **Ball Aerospace BCP 2000**, Bus dry mass = 608 kg
  - Payload Power (OAV) (EOL) / Mass Limit: 730 W / 380 kg
- **Spectrum Astro - SA 200HP**, Bus dry mass = 354 kg
  - Payload Power (OAV) (EOL) / Mass Limit: 650 W / 666 kg
- **Orbital StarBus**, Bus dry mass = 566 kg
  - Payload Power (OAV) (EOL) / Mass Limit: 550 W / 200 kg
- **Lockheed Martin - LM 900**, Bus dry mass = 492 kg
  - Payload Power (OAV) (EOL) / Mass Limit: 344 W / 470 kg
- **Orbital - Midstar**, Bus dry mass = 580 kg
  - Payload Power (OAV) (EOL) / Mass Limit: 327 W / 780 kg

  – Mission Unique Spacecraft Structure and several significant subsystem upgrades are required.

- IMDC's (GSFC) Risk Assessment & Technologies
  – *Risk on spacecraft bus is generally low, with well-understood technologies and readily available components*
  – *No significant technology development required for bus*
  – *Higher risk on instrument, especially on the enormous CCD cluster*

Baseline Configuration & Rationale

- ROM MASS: 700 kg (instrument); 500 kg (bus); 350 kg (hydrazine)
- ROM POWER: 250 w (instrument); 250 w (bus)

- MOSTLY GENERIC SUBSYSYEMS
  - EPS (electrical), C&DH (command & data handling), TCS (thermal)
- MISSION UNIQUE SUBSYSTEMS
  - ACS (attitude control), SMS (structure & mechanisms), RF (Comm)

- Evolving SNAP Bus Configuration
  - 3-axis stabilized, 4+ Reaction wheels, tactical IRUs, no torquer bars
  - Sun side w/ isolated body mounted solar arrays & anti-sun side radiators
  - Standard mono-Hydrazine propulsion, manifold & multiple tanks for slosh
    - ~ 100+ kg to raise perigee to perigee, *deplete large tanks if needed*
    - ~ 10 kg/yr for station keeping in small tanks
    - ~ 100 kg for Post Mission Disposal… *or small Solid Motors*
  - High speed data down link near perigee to Berkeley ground station.

ACS Driving Requirements

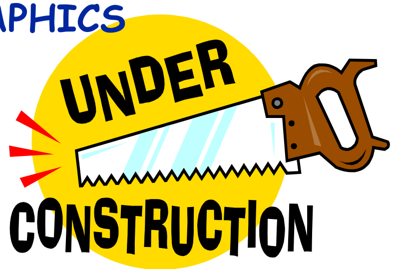
- Pointing Accuracy
  - » Yaw & Pitch : 1 arc-sec (1σ)
  - » Boresight Roll: 100 arc-sec (1σ)
- Attitude Knowledge
  - » Yaw & Pitch : 0.02 arc-sec (1σ)
  - » Boresight Roll: 2 arc-sec (1σ)
- Jitter/Stability -Stellar (over 200 sec)
  - » Yaw & Pitch : 0.02 arc-sec (1σ)
  - » Boresight Roll: 2 arc-sec (1σ)
- Sun Avoidance - VERY RELIABLE SAFE HOLD ! …and Shutter
- Earth & Moon Avoidance (mostly a result of Chandra-like orbit)

ACS Issues and Concerns from IMDC

- Jitter
  - Isolate fundamental wheel frequency through detailed analysis from manufacturer
  - Must tune wheel isolators - type, size and interface
- Flexible Mode Analysis
  - Require extensive analysis to avoid control/structure resonance
- Solar Wind Tipping, given the Large Baffle Cp-Cg offset
  - Smaller offset will minimize thruster firing frequency and propellant required for daily momentum unloading (est. 30 Nms wheels)
  - Offset will migrate with mission life, will get better with fuel depletion
- Fuel Slosh disturbance analysis will be needed
  - Minimize fuel tank Cg offset
- 3σ Pointing jitter values
  - Use current Star tracker with a very accurate Kalman Filter
  - Augment Star Tracker data with instrument data for fine pointing
  - May need to replace gyro with SKIRU-DII
- Use of Instrument guide data
  - Possible mitigation by use of more sophisticated focal plane-sensors
  - Non-white and non-bias errors must be carefully accounted

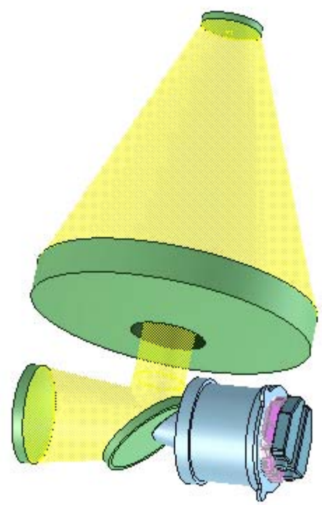
TMA-63 Optical Prescription

GRAPHICS



TMA-63 LIGHT PATH

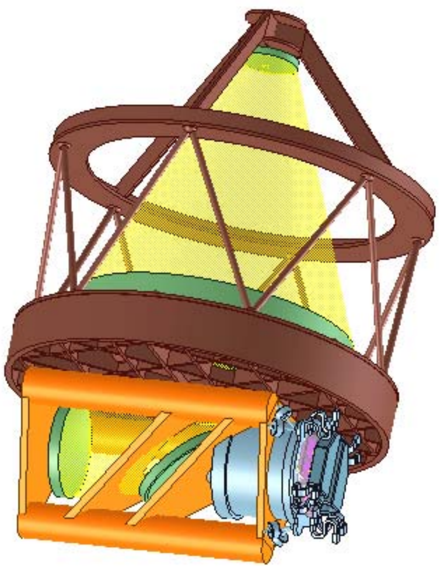
- primary
- secondary
- folding flat
- tertiary
- Camera & 140K Dewar



• add PASSIVE 140K CAMERA DEWAR

Optical Telescope Assembly (OTA)

DESIRED OTA COMPOSITE properties for the ppm Optics need
- Cyanate Ester matrix for low CME (moisture)
- High Modulus & Conductivity Fibers for sub-ppm/°C stability
- On Orbit Temperature Controlled OTA Structure
- Quasi-Isotropic Patterning
- *These are today's technology*



- add SECONDARY STRUCTURE
  low CTE - GFRP

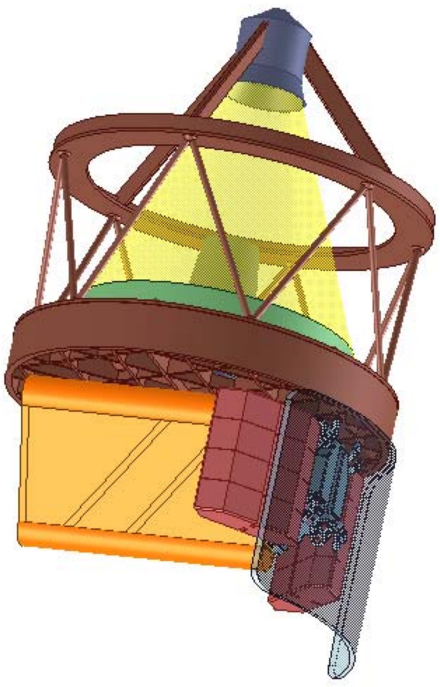
- add OPTICAL BENCH
  low CTE - GFRP

- add "OPTICS CAVITY" BELOW
  low CTE - GFRP
  - WITH THREE STIFF METERING BEAMS

Optical Telescope Assembly (OTA)

- add STRAY LIGHT SECONDARY "LAMPSHADE"

- add STRAY LIGHT PRIMARY CENTER HOLE "STOVEPIPE"

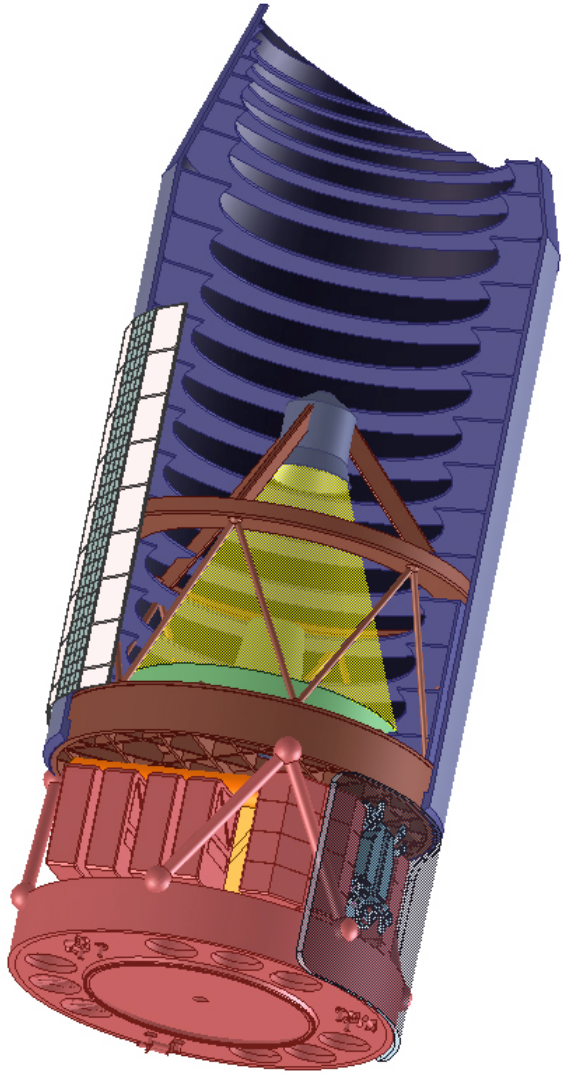


- add PASSIVE GIGA-CAM RADIATOR

- enclose OPTICS COFFIN

- add CCD FRONT END ELECTRONICS

Optical Telescope Assembly (OTA)



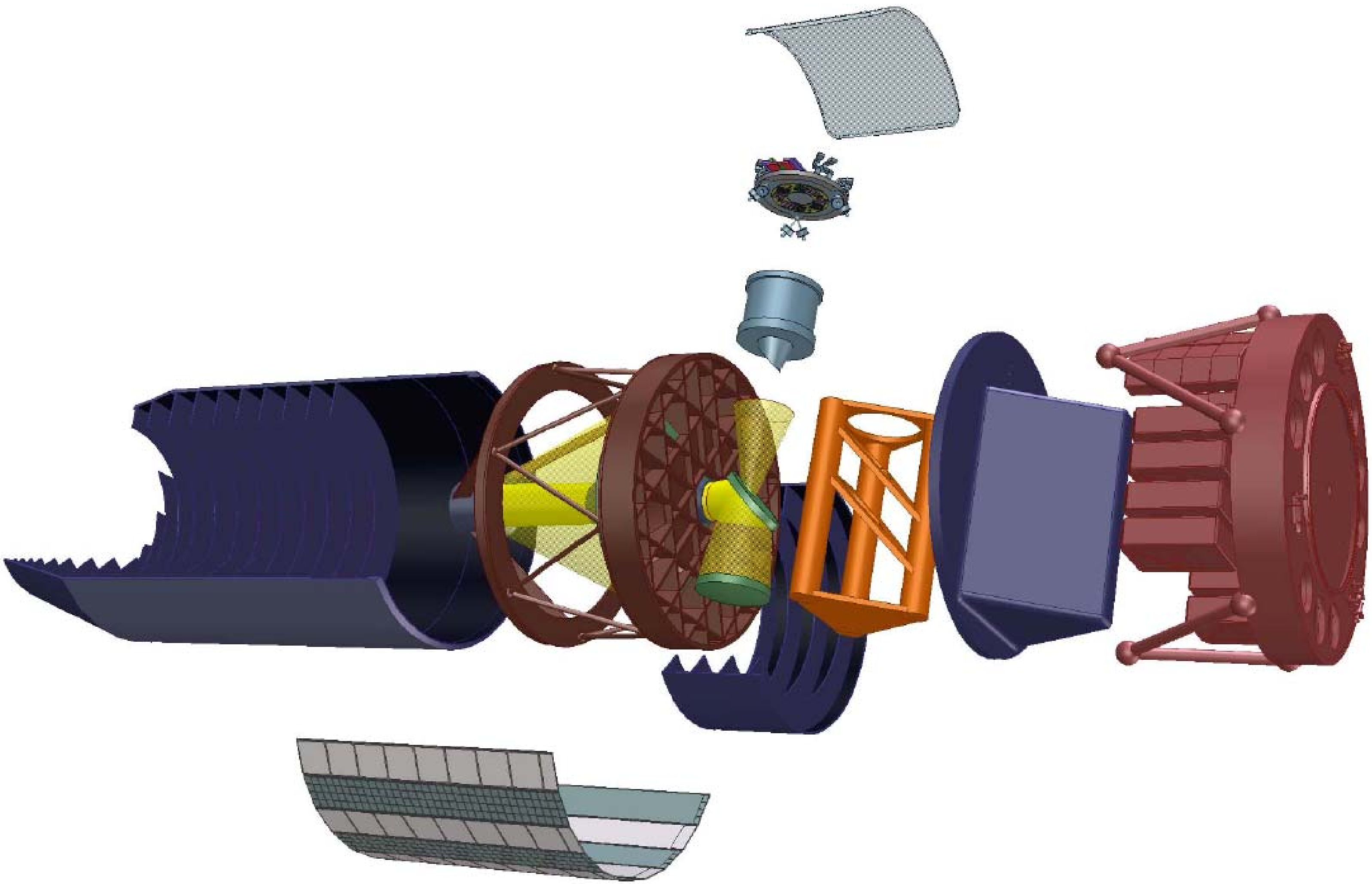
• add THERMALLY ISOLATED SOLAR ARRAY PANELS

add STRAY LIGHT BAFFLE

• add OVERALL MLI THERMAL BLANKETS

add GENERIC SPACECRAFT

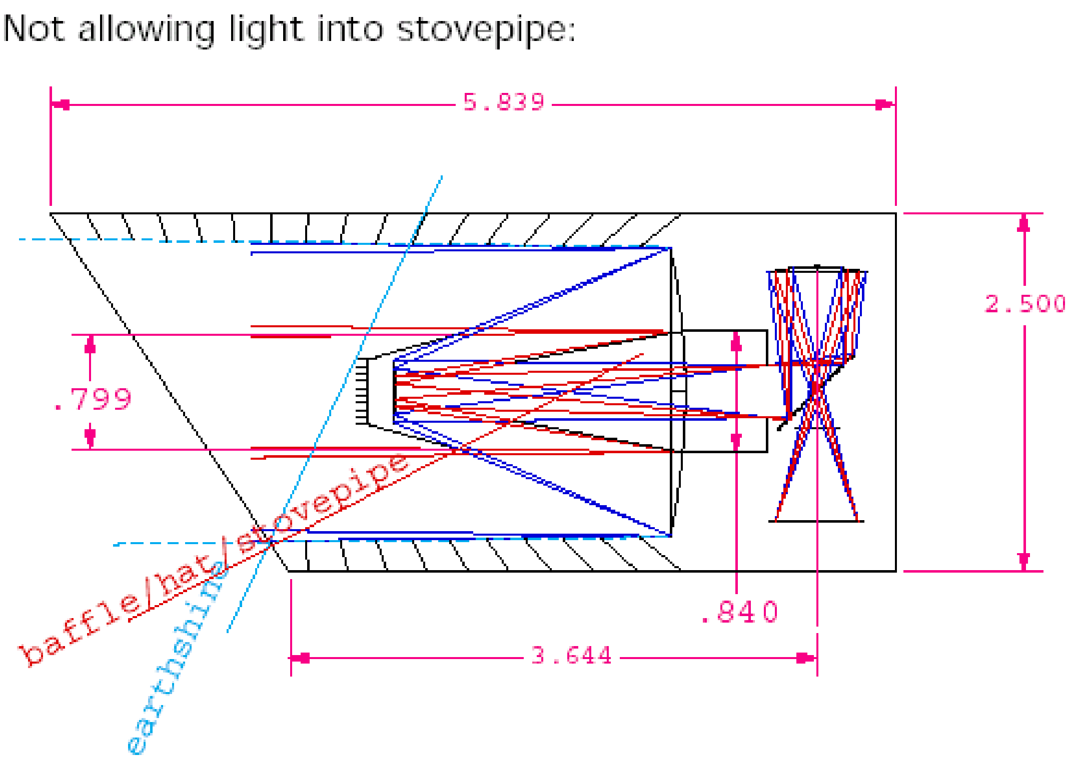
Optical Telescope Assembly (OTA)



EXPLODED VIEW

Optical Telescope Assembly (OTA)

STRAY LIGHT BAFFLE

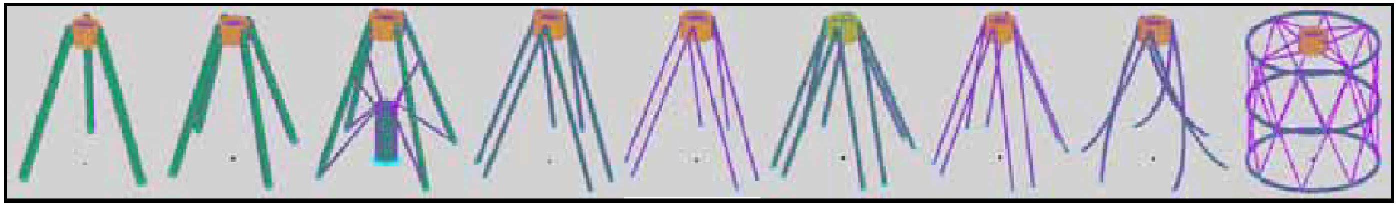


- Ordinary Precision (±mm's) Aluminum Shell Structure would be Adequate
- The necessary Knife Edge Geometry is established
    - Minimum of two diffraction bounces to Primary
    - Longer Baffle -> Lower Obscuration

- 'One Shot' Split Lightweight Front Doors are a Viable Option !

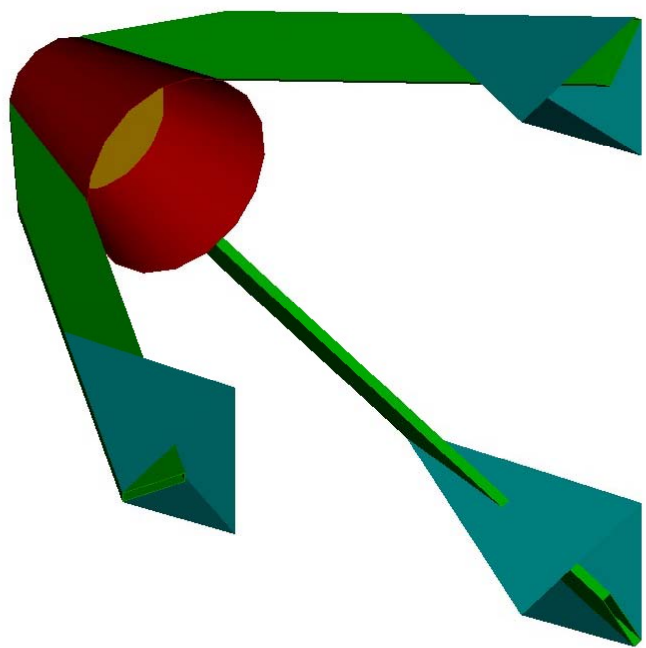
Optical Telescope Assembly (OTA)

Secondary Metering Structure



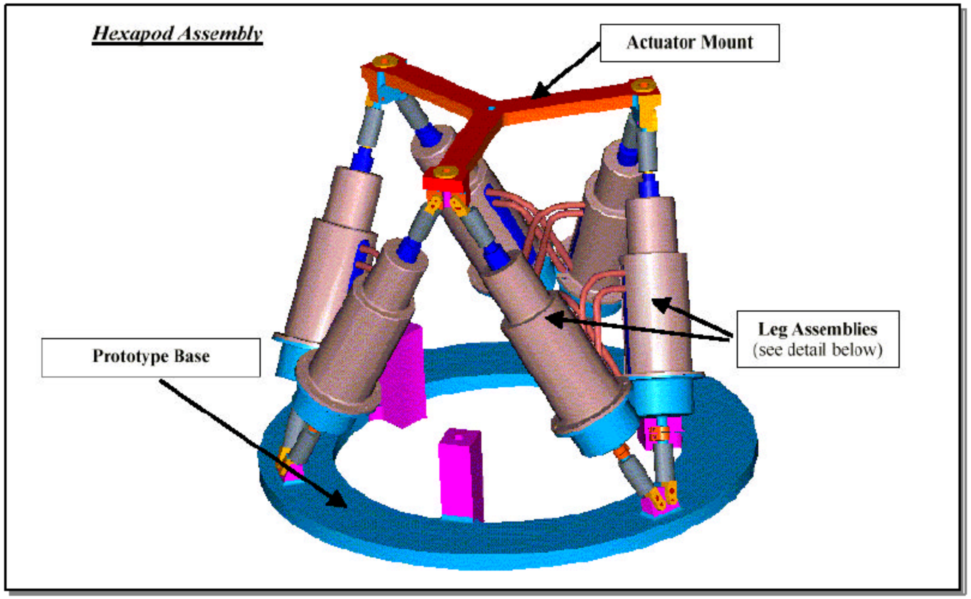
	Tripod	Quadrupod	Cross-Braced Quadrupod
# legs	3	4	4
outside diameter	112	102	67
wall thickness	1.0	1.0	1.0
obscuration	8.6	10.4	6.8
interference spikes	6	4	4
lowest violin mode	197	180	[illegible]
lowest global mode	35	[illegible]	34
mass of composite	6.4	7.7	8.9
mass of fittings	39.7	41.3	16.1
total mass of metering structure	46.1	49.0	25.0

HPS-113005-0001 / SNAP Meeting, LBNL, November 3rd, 2000 / E. P



- INSERT LATEST BESUNER / LAFEVER RESULTS HERE !

OTA Active Mechanisms



HEXAPOD ADJUSTOR

or Secondary Mirror "focus knob"

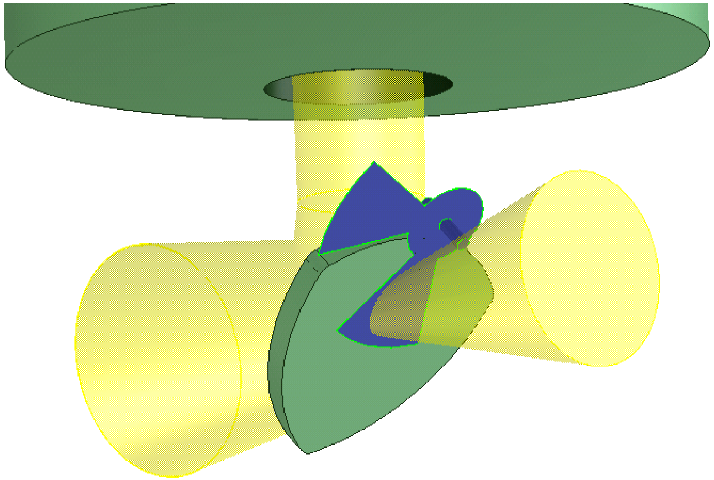
— micron steps & mm range needed

— several such designs have flown

—HST, Fuse, & more...

— Fast Steering Actuators in Series

—Piezo's or Magnetostrictive



SHUTTER MECHANISM

"Bow-Tie" style is attractive

- more uniform exposure times
- momentum compensation planned

0.1 ± 0.005 sec timing anticipated

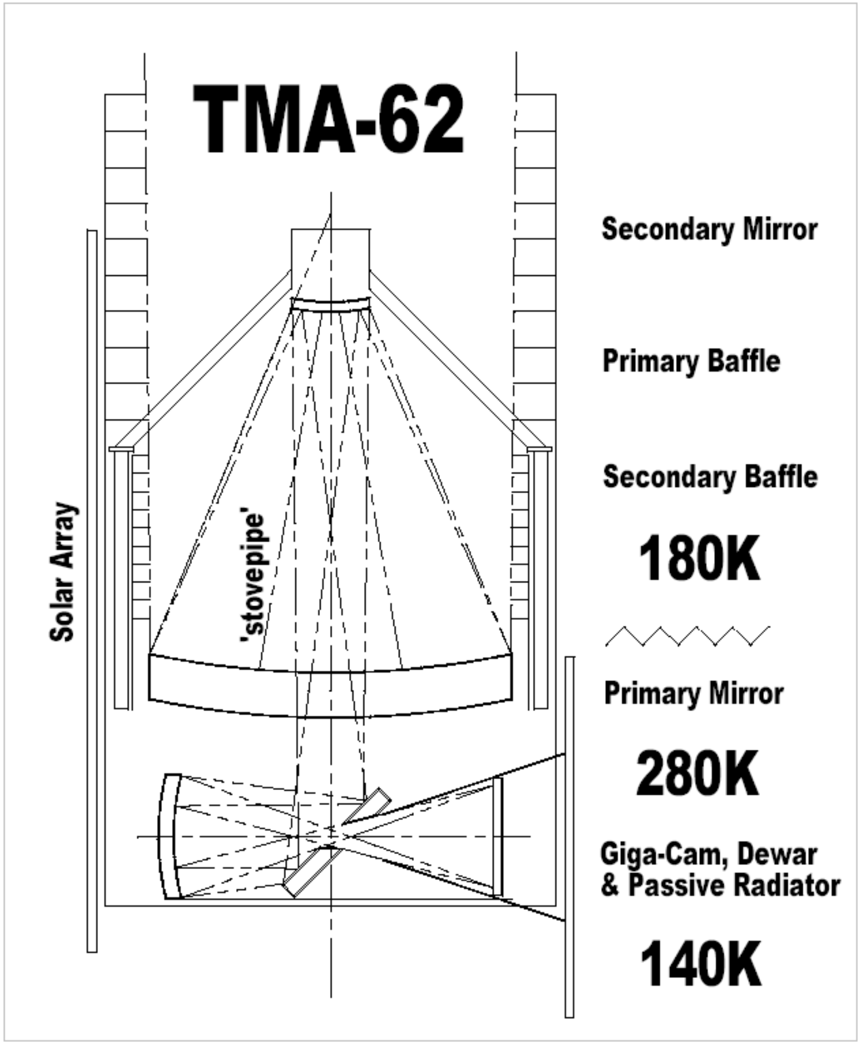
- PRESENT BASELINE IS NO MOVING FILTER WHEELS !
- THE FAST STEERING MIRROR (secondary) IS AN OPTION
- TERTIARY HEXAPOD ADJUSTER IS ALSO AN OPTION

OTA THERMAL

OPTICS: Build, Test, & Fly Warm… like Hubble !

KEY DESIGN FEATURES

- High Earth orbit (HEO) to minimize IR Earth-glow loads
- GaAs cell - OSR striping of the (hot) solar array panels
  - Front surface heat rejection OK
  - Optical Solar Reflectors are back silvered Quartz tiles ($\alpha \sim 8\%$, $\varepsilon \sim 80\%$)
- Low emissivity silvered mirrors
- Thermal Isolation mounting and MLI blanketing



OTA WARM OPTICS THERMAL ROM

LARGE STRAY LIGHT BAFFLE (~180K)

478 w	Absorbed Sunlight if MLI covered (α^* ~ 2%)
100 w	Telescope Internal Parasitics and 5m^2 Solar Array coupling (MLI behind)
< 62w>	Radiant Loss from Baffle Outer Cylinder (ε^* ~ 2%)
<480w>	Radiant Loss from Baffle Open BB End (large axial Temp gradient)

PRIMARY MIRROR HEATER LOAD AT 280K

< 6w>	Radiant Loss to Space (ε ~ 2%)
<14w>	Radiant Face Loss to 180K Baffle (ε ~ 2%)
< 4w>	Radiant MLI covered Edge Loss to 180K Baffle (ε^* ~ 1%)
< 1w>	Radiant Loss from Central MLI Stovepipe BB hole

SECONDARY MIRROR HEATER LOAD AT 280K

<<10w>	Radiant and Conductive Losses to Baffle and Structure (Est.)

TBS	HEATED SECONDARY STRUCTURE (black MLI covered)

OTA CAMERA THERMAL ROM

PASSIVE GIGA-CAM 140K DEWAR THERMAL BUDGET

32 w	Radiating Capacity from 2m^2 unobstructed 130K Radiator to Space
< 4w>	Radiator Thermal Isolation Mounts & MLI behind

RADIANT COUPLING LOSSES

< 6w>	CONICAL Cosmic Ray Shield - MLI outside (ε^* ~ 1%)
< 4w>	Open End CONE Blackbody Loss to warm Coffin Cavity

CONDUCTIVE COUPLING LOSSES

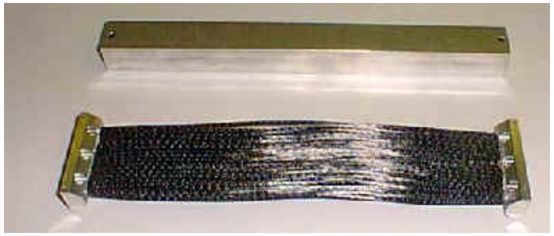
< 1w>	Giga-Cam Thermal Isolation Mounts
< 2w>	Dewar Thermal Isolation Mounts and Cold Plate Gaskets
< 1w>	Electrical "Flex-Print" (~ 5800 traces)
< 6w>	Average Electrical Power Dissipated in CCD's
~ 8w	ROM MARGIN
~10°C	Gradient allocated for Cold Plate, Radiator, and Flex-Links

OTA THERMAL

SOME "KEY ITEM" THERMAL HARDWARE EXAMPLES

HESSI Sapphire & S-LINK
High Conductivity Thermal Strap
~ 700 layers Al Foil

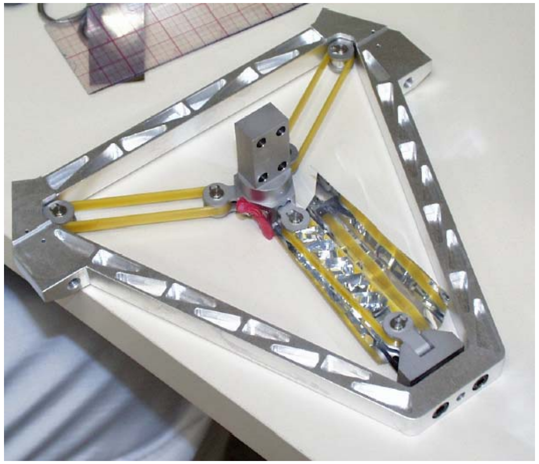
8x higher Conductivity Graphite Fiber
based Thermal Strap Assembly



Mariner 6&7 (Mars '69)
IR Spectrometer
Joule-Thompson Cryostat
Thermal Isolation Mount

OTA THERMAL

SOME RECENT THERMAL HARDWARE EXAMPLES



HESSI S-Glass Thermal Isolation
Strap Assembly
~140mW loss for the set at 200°ΔT

HESSI COLD PLATE ASSEMBLY
supports 38 kg Ge Detector
Assembly under Vacuum

HESSI DETECTOR ASSEMBLY
Extensive Thermal Isolation
used to achieve 75K with only
~3W of active cooling

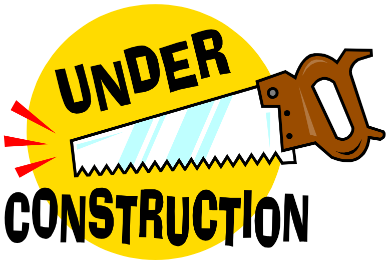
OTA THERMAL +

SOLUTIONS FOR COMMON CONTAMINATION CONCERNS

- Moisture / Frost is a Primary Culprit
  - FEP teflon MLI blanketing is a stock item (0.005% hygroscopic)
  - Cyanate Ester resins absorb ~7ppm water vs ~70 ppm for epoxies
  - Concentric gold plated cans tend to be heavy & less efficient
- "Structured" Cool-down Approach
  - Focal Plane Camera is the last item to cool-down in LEO
  - Residual moisture can be frozen into structure & blankets
- Preferred Vent Paths & Cover Strategies are Frequently Used

SNAP Engineering Requirements

- Does this make sense… (its long & boring !)



engineering STATUS

- **CAMERA needs and viable approaches are known and actively pursued**
  - **Thermal management calls for continuing vigilance**

- **TELESCOPE packaging options and requirements are well defined**
  - **Several Light-weighting Options are actively being Considered**
  - **Our team's desire is to maintain technology/vendor flexibility**

- **SPACECRAFT can be a generic RSDO *(interagency)* procurement**
  - Instrument - ACS interactions calls for continued clever thinking

- **MISSION...**

R&D ACTIVITIES

- Expand Instrument and Spacecraft Project Office Infrastructure needed to properly 'Architect' the SNAP Mission
  - Typical Instrument Engineering Team

    Instrument Manager, Structural, Thermal, Cryogenic, Mechanisms, Optics, Quality Assurance, Contamination, Configuration Management, Procurement

  - Typical Spacecraft Engineering Team

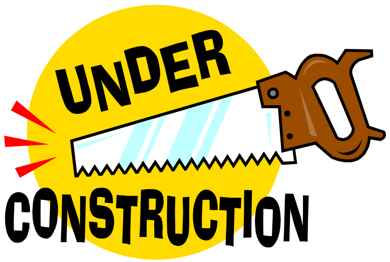
    Bus Manager, Integration & Test manager, Ground Segment manager, Launch manager, Structure and Mechanisms, Thermal control systems, Attitude control systems, Flight Dynamics, Electrical power systems, Command & Data Handling, Telecommunications, Flight Software

- Develop the "Proof of Concept" Spacecraft & Instrument Designs
  - Detailed Camera and Dewar Mechanical, Thermal, and Electrical Designs
  - Partner with Industry(s) to develop Telescope and OTA Structure
  - Develop Compatible Primary, or the Load Bearing Spacecraft Structure
  - Conceptual Design of Test / Ground Support Equipment needs

R&D ACTIVITIES

- **Design Activity Flow Downs, or Design Related Activities**
  - Preliminary Coupled Loads Analysis (includes Launcher)
  - Preliminary Observatory Level Integrated Thermal Model
  - Generate Viable Optics Test plan, plus the general I&T plans
  - Develop draft Instrument & Spacecraft Interface Documents
  - Science and Mission Requirements Review(s)
  - Preliminary Failure Modes (FMEA) and Probabilistic Risk (PRA)
- **Generate the Long Lead Item Optics Procurement Plan**
- **Generate an EM Spacecraft & Telescope Plan and Schedule**

R&D SCHEDULE



SUMMARY & COMMENTS

- Delta 3/4 LV Is Not Mature Today, but NASA Is Committed.
  - Delta 4 build in process at KSC for EUTELSAT *…summer '02*

- SC Bus has its Challenging Aspects, but No New Technology

- Composite OTA Structures Are Well Understood and this Technology continues to advance

- SNAP has several Options for Lightweight, Low CTE Mirrors
  - (later by M. Lampton)

- Passive Thermal Approach is Viable for Camera

- Build, Test, & Fly Warm Is an Appealing & Proven Approach